a 220-volt alternating circuit, frequency 50, and the pressure across the high-tension terminals was measured, with the apparatus working the two spark-gaps in series. This was found to be 3,600 volts. The frequency of the diathermy current was measured and found to be 667,000 cycles per second. The capacity of the condenser in the oscillating circuit, which consisted of two condensers in series, was measured and found to be 0·0054 microfarad."

3. Diathermy Machines by Watson and Sons.

Watson and Sons construct three distinct models of diathermy machine, one of medium size (Standard Model), one of large size (Power Model), and one which is intermediate in size between the other two (Therapeutic Model).

(a) *Standard Model.*—This is illustrated in Fig. 15. The cabinet has perforated metal sides. In its lower half the static transformer can be seen. In the upper half are the condensers, oscillator and resonator. The top of the cabinet is made of marble and on it are mounted the amperemeter and spark-gap. The latter is of special design. It can be seen on the right side of the amperemeter.

The primary winding of the transformer is tapped so that the current supplying the machine can be taken through part of the winding or through the whole. A crank for the purpose can be seen on the top of the cabinet on the left side in front. The secondary coil of the transformer is wound so that the current induced in it has a voltage of 5,000. The main condenser is composed of thin zinc plates separated by sheets of glass. It has a capacity of 0·005 microfarad.

The spark-gap is shown in diagram in Fig. 16. The spaces across which the sparks pass are two in number. They lie between a metal disc *ab* and two metal electrodes *c* and *d*. The two latter are fixed, and the disc is movable. By turning the ebonite handle *h* the disc can be raised or lowered, thereby widening or narrowing the spaces between the electrodes and the disc. The spark-gap is enclosed in a cylindrical chamber of aluminium. Each end of the cylinder is closed by an aluminium ring fitted with a mica centre.

Through the mica centres pass the electrodes so that the latter are insulated from the metal chamber. Radiating fins (not shown in the figure) are attached to the electrodes to prevent overheating.

The air of the chamber is replaced by coal gas or vapour of petrol or acetone. Taps for entry and exit of the gas are shown at *f* and *g*. If gas is unobtainable a little acetone or petrol is placed in the chamber. It evaporates and replaces the air from the chamber. The taps *f* and *g* are then closed.

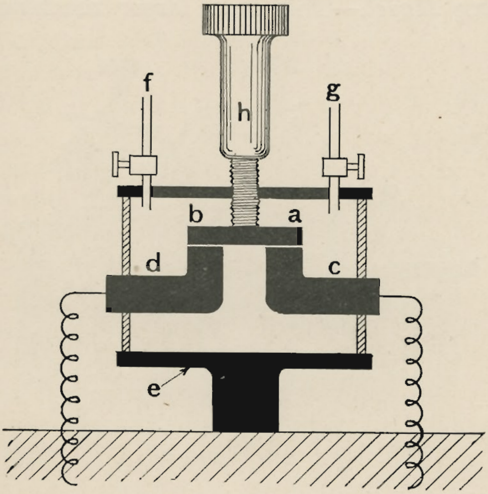

Fig. 16.—Spark-gap fitted to diathermy machines by Watson and Sons (diagrammatic).

The metal surfaces between which the sparks pass are faced with silver.

The oscillator is a spiral coil of thick wire. The resonator is similar, but the turns have a smaller diameter. By rotating the coupling handle (seen in Fig. 15, in front of the amperemeter) the resonator can be made to slide into the oscillator, both spirals having the same long axis. In this way the current in the resonator can be increased from zero to maximum. The circuit containing the resonator includes the amperemeter and two small condensers. The latter are similar in design to the main condenser. Each has a capacity of 0·003 microfarad. These condensers are in series with the patient and the resonator.

The current yielded by this machine has a frequency of 850,000 cycles per second.

This machine can be connected to a Tesla transformer and used for producing a high-frequency effluve. A connecting link is provided so that the primary coil of the transformer can be introduced into the oscillating circuit (*i.e.* the circuit containing the oscillator, secondary coil of transformer and spark-gap) of the diathermy machine.

(b) *Power Model.*—This is a larger machine than the Standard Model. It is shown in Fig. 17. It contains two spark-gaps and condensers of larger capacity. Different methods are adopted for regulating the incoming and outgoing currents. The plan is shown in Fig. 18.

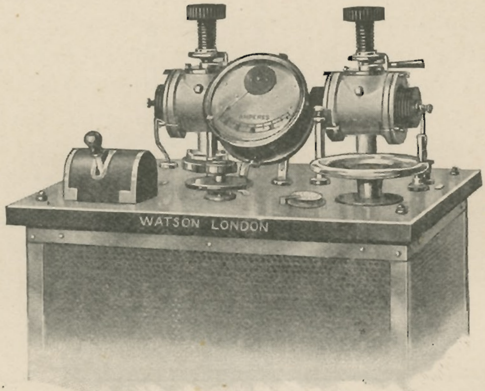

FIG. 17.—" Power " diathermy machine. (Upper part only is shown.)

Between the primary coil of the transformer and the main are introduced two additional coils, one in parallel (AB, Fig. 18) and the other in series (CD). The number of turns introduced can be varied. The coil introduced in parallel is known as an " auto-transformer " and consists of a single layer of wire wound around a laminated iron core. By varying the number of coils the voltage of the current passing along the primary winding (EF) of the static transformer can be adjusted. The coil introduced in series is a "choke coil." By altering the number of turns introduced the amount of self-induction (inductance) which takes place in the primary winding of the transformer can be varied. By these methods the incoming current can be regulated through a necessarily wide range. In the secondary winding (GH) of the transformer a current is induced at a voltage of 5,000. The main condenser (K) is made of sheets of tinfoil separated by waxed paper. It is immersed in oil. It has a capacity of 0·007 microfarad. Two spark-gaps (L and L′) are used. Each is similar to that fitted to the Standard Model. They are placed in series.

In the circuit containing the secondary coil of the transformer, the condenser and spark-gaps a high-frequency current is generated. The oscillator consists of a few turns of thick wire (MN) wound round a former which is 6 inches in diameter. Unlike the machines previously described the resonator is in direct continuation with the oscillator. It is constituted by the coil NO. The current in the resonator is the diathermy current which passes to the patient. It is led off by way of two wires, one of which is connected to the end O of the resonator, the other to N. In the patient's circuit are two condensers, P and Q. They are similar to the main condenser K and are immersed in oil. Each has a capacity of 0·006 microfarad. The amperemeter S is inserted in the patient's circuit.

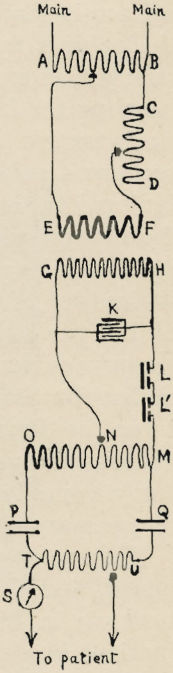

FIG. 18.—Explanatory plan of Power Model.

The current passing to the patient is regulated by means of the wire coil TU. This coil is inserted in parallel across the wires leading the current to the patient's terminals. Presenting, as it does, a very high resistance to oscillatory currents, the current in the resonator passes almost wholly to the patient. If, however, one of the wires passing to the patient is connected, not to one end of the coil TU but to some intermediate point, some of this high-resistance coil is now in series with the patient and the current passing to him will be reduced. The coil TU is composed of about twenty spaced turns of bare wire wound on a hollow drum. The drum is geared to the handle seen in Fig. 17 on the top of the cabinet in front (right side) and a variable contact is arranged so as to bear on the wire spiral (TU in Fig. 18). By turning the handle the drum is rotated and the variable contact travels along the coil TU. By this method as many turns as desired can be placed in series with the patient and the strength of the current regulated as required.

The current yielded by this machine has a frequency of 1,000,000 cycles per second.

The output of the Power Model is stated by the makers to be 100 per cent. more than that of the Standard Model. The supply current is correspondingly greater, the maximum input for the Standard Model being 650 volt-amperes, and that for the Power Model being 1,700 volt-amperes. The latter can, however, be reduced when light work is performed and only a small output is necessary. There is consequently no unnecessary waste of primary energy.

(c) *Therapeutic Model.*—This is a combination of the Standard and Power Models. The circuit is similar to that shown in Fig. 18, except that the current passing to the patient is regulated by moving the contact N (Fig. 18) along the coil OM. The coil TU is absent. A single spark-gap is used as in the Standard Model. The main condenser is the same as that fitted to the Standard Model. The small condensers in the patient's circuit are made of metal sheets separated by plate glass and each has a capacity of 0·003 microfarad.

Both in this machine and the Power Model a link connection is provided so that a Tesla transformer can be attached for production of high-frequency effluve.

4. Diathermy Machines by Schall.

The firm of Schall and Son make three models of diathermy machine. One of these, the "Universal," is of medium size and is suitable both for medical and surgical work. The second is smaller in size and is *portable*. It is suitable for surgical and minor medical work. The third is quite small, weighing 36 lbs. It is suitable for minor surgical work only. The second model derives its supply from a *direct*

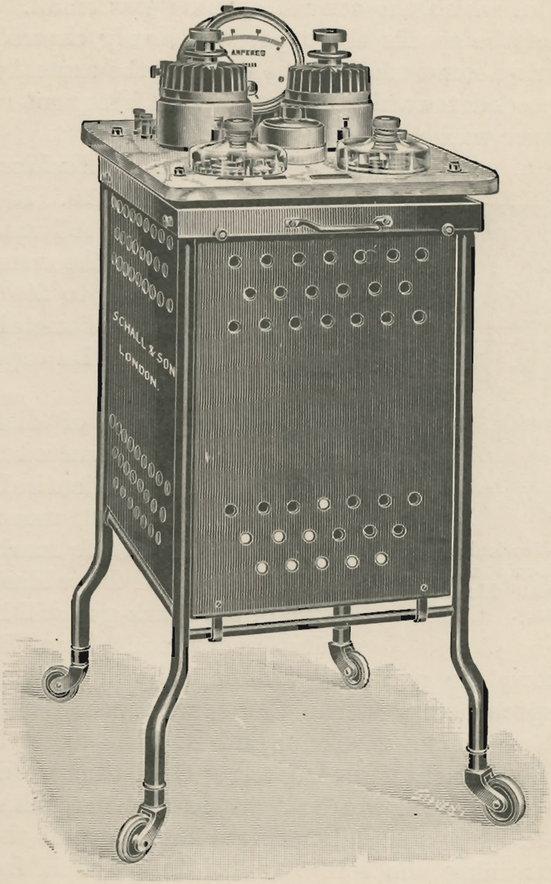

Fig. 19.—The "Universal" diathermy machine.

current main. It weighs 62 lbs. The Universal machine weighs 280 lbs.

The original form of diathermy machine used in England was by Schall. This was used at St. Bartholomew's in 1909. It was fitted with a spark-gap designed by Baron Le Pel. It consisted of metal discs separated by paper washers, of which the central opening was small. During passage of the sparks the paper was slowly charred away. The charring commenced at the edges of the central opening and proceeded towards the periphery. Frequent renewals of the paper washers were necessary.

(a) " *Universal* " *Machine.*—This is illustrated in Fig. 19. It derives its supply from the AC main. In the secondary coil of the transformer the voltage is raised to 2000. The condenser is made of metal sheets separated by glass. Its capacity is 0·005 microfarad.

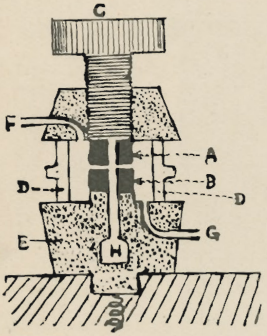

FIG. 20.—Vertical section of spark-gap fitted to " Universal " Model (diagrammatic).

The spark-gap is of distinctive design. It is constructed in two portions, each being identical. They can be seen in Fig. 19, mounted on the hinder part of the marble slab forming the top of the cabinet. The design of the spark-gap will be more easily understood from Fig. 20, which shows the parts diagrammatically in section. The narrow space across which the sparks pass is situated between two copper blocks, A and B. The upper block is attached to a finely threaded screw C so that its distance from the lower block can be adjusted and the width of the gap varied. D is a porcelain ring. This supports the metal block containing the screw C and insulates it from the lower block E. The latter is fixed. The upper block containing the screw can be lifted off for cleaning. When the machine is in operation the upper block is maintained in position by bolts. By means of the inlet and outlet pipes, F and G, a stream of coal gas can be passed through the spark-gap.

In places where coal gas is unobtainable methylated spirit can be used. The spirit is stored in a small reservoir. This can be seen in Fig. 19, behind the switch. Spirit passes from it into the small chamber H (Fig. 20), thence by capillary action along a wick in the channel above the chamber into the narrow space between the copper blocks A and B. The heat of the sparks vapourises the spirit and decomposes it, forming hydrogen. This gas occupies the space between the blocks. It is a good conductor of heat and prevents the blocks from becoming too hot.

The oscillator consists of a cylindrical spiral of insulated wire with the turns in close proximity. There is no separate resonator. The diathermy current for therapeutic use is taken from the oscillator. Wires are attached to the oscillator spiral at intervals along its course. These wires are brought into connection with metal studs secured to the marble top of the cabinet. One of the wires is attached to one end of the oscillator spiral and leads to one of the terminals to which the patient's electrodes are connected. The other terminal can be brought into connection with any one of the metal studs by rotating the crank lying within the glass cover seen on the marble slab in front (left side). It can thus be brought into connection with various points along the oscillator. The greater the length of oscillator spiral included in the patient's circuit the stronger the current and *vice versa*. In this way the current can be varied.

By means of the crank enclosed in the glass chamber seen on the right side of the marble slab in front (Fig. 19), additional condensers can be introduced into the oscillating circuit, thereby increasing the capacity of the main condenser. By this means a stronger current can be delivered to the patient when the body circuit is lengthy and has a high resistance.

(b) *Portable Model.*—This is shown in Fig. 21. Unlike the machines previously described it is supplied from the *direct-current* main. The voltage of the latter must be 200.

In this machine there is no transformer, and the condenser is charged directly from the main. The condenser discharges across a spark-gap and along a primary solenoid (oscillator).

The high-frequency current utilised for treatment is taken from a secondary solenoid (resonator); the ends of the latter are connected to the two outermost terminals seen on the right side of the marble slab forming the top of the case. The two middle terminals are connected to intermediate points of the resonator. By means of an electro-magnet the current, which is taken from the main, is automatically short-circuited the moment the condenser is charged. The latter then discharges across the spark-gap and along the solenoid. The short circuit is then interrupted and the condenser is again charged. This alternate charging of the condenser and short-circuiting of the charging current, discharging of the condenser and interruption of the short-circuit, proceeds continuously. It is effected by means of the electro-magnet and an interrupter. The electro-magnet is under the wire network hood seen on the marble slab. The air of the spark-gap is replaced by methylated spirit

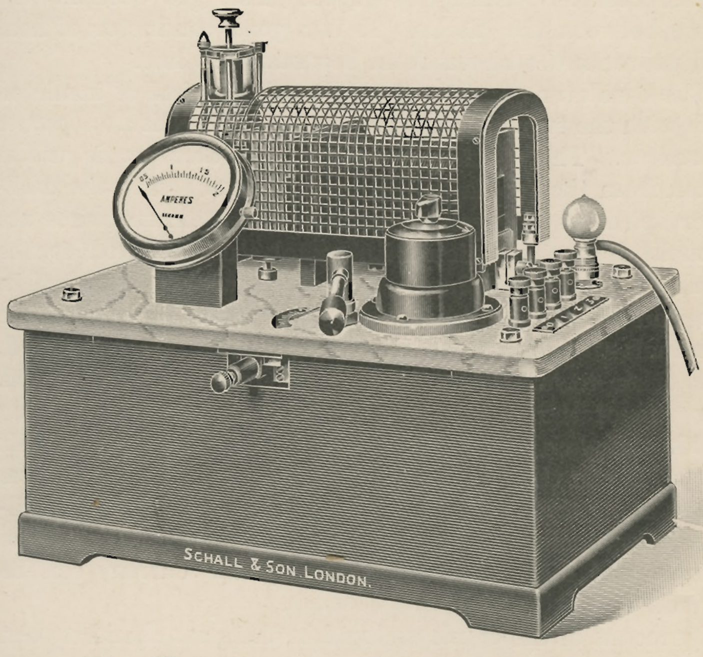

Fig. 21.—Portable Model diathermy machine for use on *direct-current* main.

supplied from the small glass vessel (seen on the top of the hood) or by coal gas. Coal gas is better than spirit. It is led to the gap by way of a metal pipe and burnt as it escapes from a narrow tube by the side of the glass vessel. By means of an ebonite screw at the left side of the metal hood (hidden from view in the figure), the width of the spark-gap is regulated. On the front of the marble slab is seen a

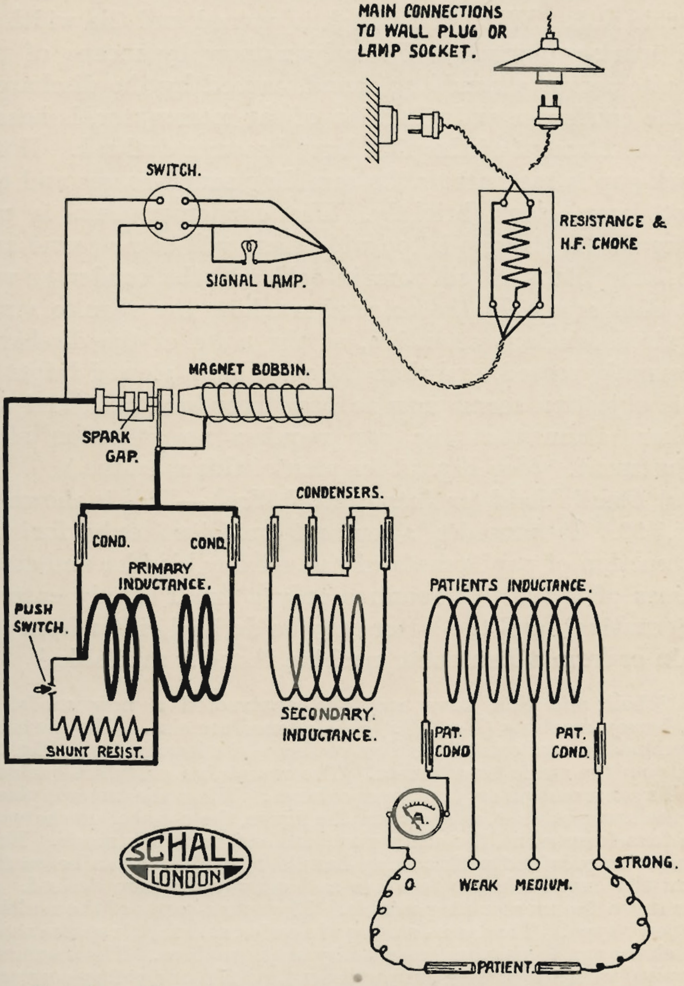

Fig. 22.—Plan of diathermy machine illustrated in Fig. 21.

large switch, which, when opened, allows the main current to charge the condenser. On the left of the switch is the coupling handle, which brings the resonator over the primary solenoid. A small pilot lamp is seen on the right of the marble slab. When the switch is opened and the width of the spark-gap made sufficiently narrow by means of the ebonite screw, a rumbling sound, caused by the discharges of the condenser and vibration of the interrupter, is heard, and the filament of the pilot lamp becomes dull red. If the spark-gap is too narrow the rumbling sound ceases and the pilot lamp glows brightly. The condenser then is not charged. If the gap is too wide there will be no sound and the lamp filament will remain cold and the condenser will not discharge. In the original machine the ebonite screw required constant attention, as the noise of the discharge frequently ceased, and then the pilot lamp glowed brightly. This objection seems now to have been removed, and the makers claim that the gap requires no attention after adjustment. (See Fig. 22 for plan of this machine.)

(c) *Small Model for Intra-vesical Work.*—This is shown in Fig. 23. It provides a current sufficient only for the destruction of papillomata of the urinary bladder and small masses of tissue. It requires only a small supply current (alternating), and the latter may be derived either from the main or from a Pantostat machine if one is available.[1]

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[1] Schall and Son have recently constructed a new model of diathermy machine (Fig. 24). It is of medium size. The parts are assembled in two cabinets. One of these (the lowermost in Fig. 24) contains the static transformer. The remaining parts are enclosed within, or mounted on, the upper cabinet. When the latter is placed on the lower cabinet, as shown in the figure, the connections between the transformer and the other parts are automatically made. Each cabinet is provided with a strap-handle by which it can be carried from the owner's house to a car and conveyed where desired. In this sense the machine is portable. The spark-gap is of the multiple " open " type. There are four gaps in series, and the air spaces across which the sparks pass are bounded by tungsten discs. The machine is supplied with alternating current from the main or a rotary converter and is constructed so as to take current either at 100 volts, 150 volts or higher. The five terminals seen on the top of the upper cabinet are connected to the ends and three intermediate points of the resonator. The voltage of the current received by the patient can therefore be varied within wide limits. The current derived from the outermost terminals can attain a voltage much higher than is possible in machines of the same size and can spark across an air space of an inch.

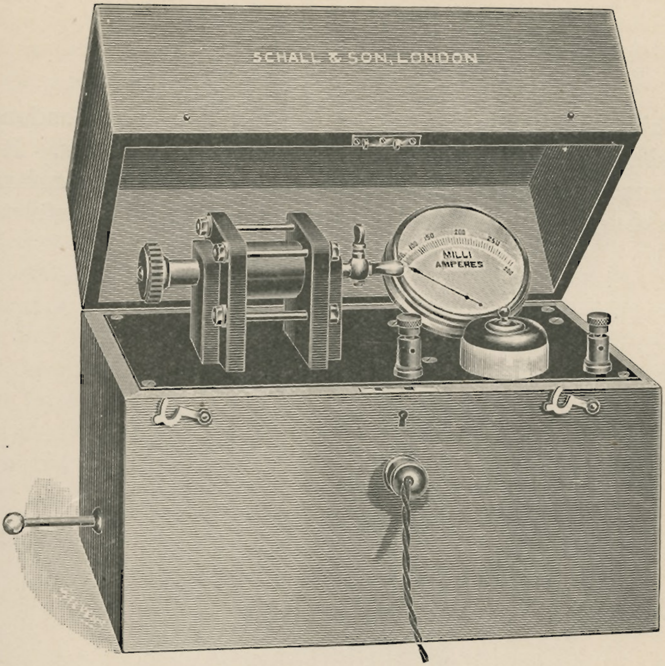

FIG. 23.—Small portable diathermy machine for minor surgical work.

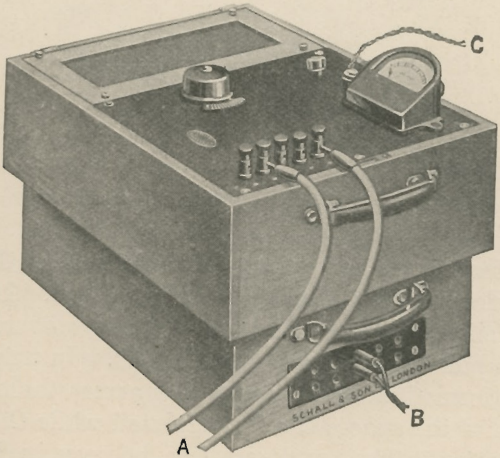

FIG. 24.—Schall's most recent model of diathermy machine.

section at E and F. By means of this ring the silver discs are maintained in close proximity without contact. In this way a gap 1 mm. wide is formed. The lower disc is perforated at its centre so as to communicate with the channel H, which contains a wick. This wick leads methylated spirit from a couple of reservoirs. These can be seen in Fig. 30 on each side of the metal hood enclosing the spark-gap. The upper metal block C can be raised off the lower by a hinge movement at K. This is effected in the actual

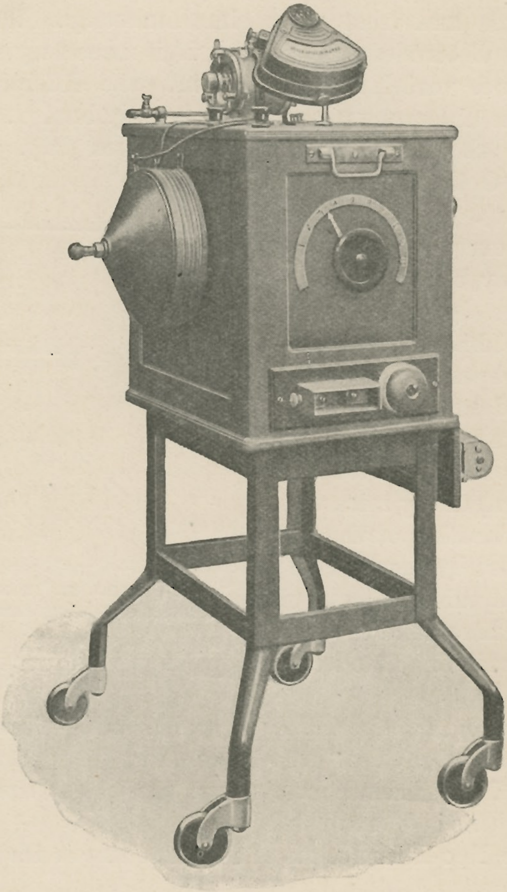

Fig. 32.—Diathermy machine by Gaiffe-Gallot et Pilon.